The Late Paleozoic - Early Mesozoic Chocolate Formation of southern Peru: New data and interpretations

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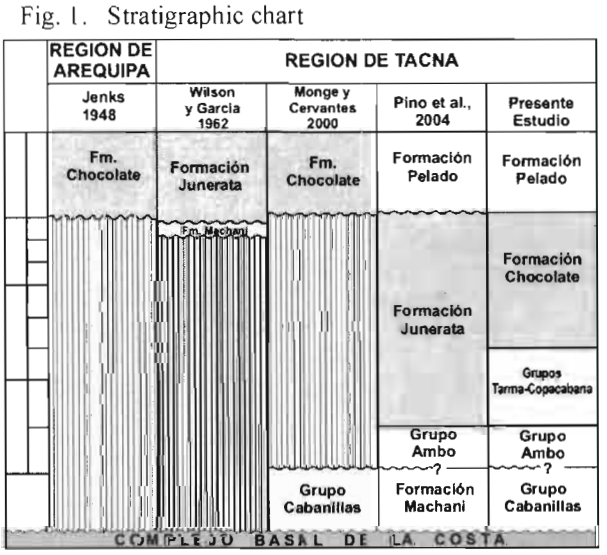
INTRODUCTION

The Chocolate Formation is exposed in southern Peru between the cities of Nazca and Tacna, mostly in the Pacific slopes of the Cordillera Occidental and along the coast. This lithostratigraphic unit was initially described near Arequipa by Jenks (1948; "Volcánicos Chocolate"), who assigned a Jurassic age to it. It consists of a succession of volcanic rocks, sandstones, and conglomerates. Near the top of the unit, a Sinemurian ammonite was found in a fossiliferous limestone intercalation. In Tacna a similar unit was mapped as "Junerata Formation" by Wilson & García (1962) and later equated with the Chocolate Formation (Monge & Cervantes, 2000). Recent studies have suggested that the base of this unit might be as old as Late Carboniferous (Pino et al., 2004; Sempere et al., 2004). Because the Chocolate volcanism is likely to have been active in the middle Permian, it partly represents a coastal equivalent of the Mitu volcanism known in the Eastern Cordillera.

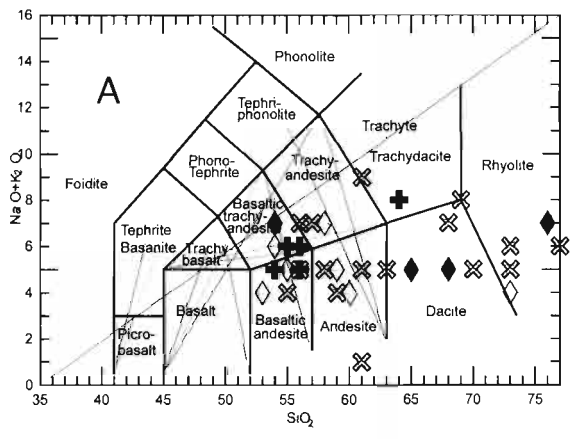
Fig. 1. Stratigraphic chart

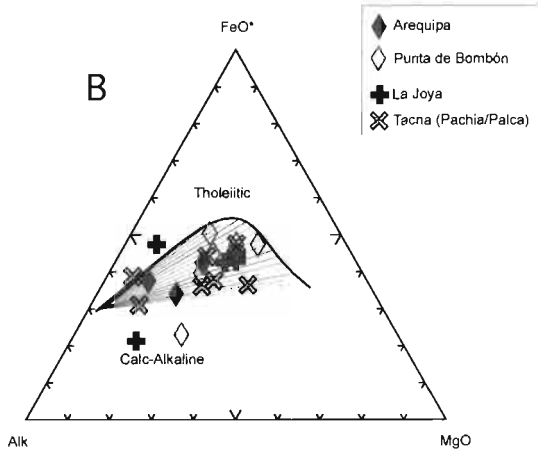


STRATIGRAPHIC RELATIONSHIPS

In the Río Sihuas, Murco, La Joya and Punta de Bombón, the Chocolate Formation overlies the Precambrian basement or Paleozoic strata, and conformably underlies the Upper Liassic-Lower Dogger carbonates of the Socosani Formation. North and northeast of Tacna, the Chocolate Formation conformably underlies the Liassic Pelado Formation and conformably overlies sandstones and mudstones that have yielded fossils typical of the Mississippian Ambo Group (Pino et al., 2004; Sempere et al., 2004), and others possibly indicative of a Pennsylvanian and/or Permian age. Along the coast (Pocoma, Punta de Bombón, Puerto Viejo), the Chocolate Formation conformably overlies clastic strata of probable Late Paleozoic age. These relationships suggest that the base of the Chocolate Formation is likely to be Late Paleozoic in age, and possibly Middle Permian (Fig. 1).

LITHOLOGIES AND GEOCHEMISTRY





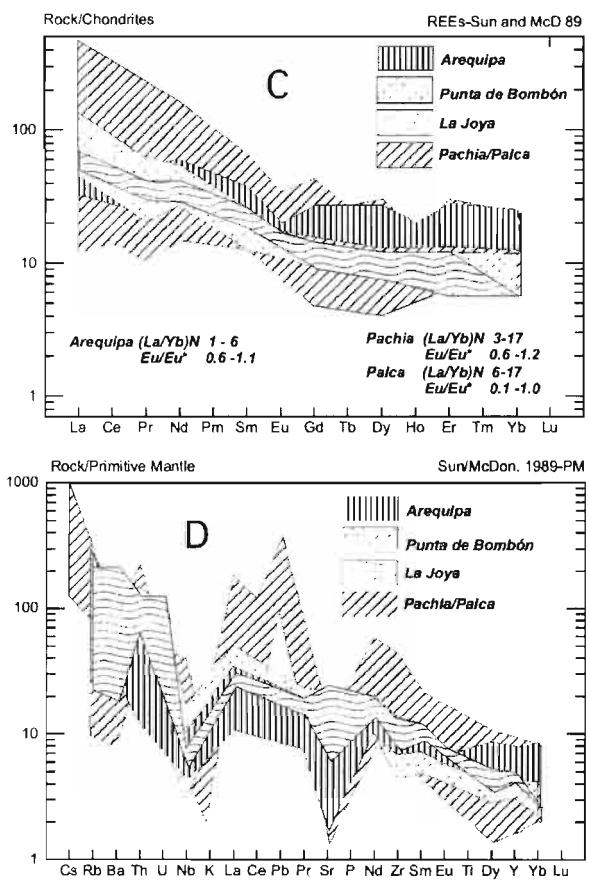
Alternating pyroclastic flows, lavas and associated subvolcanic rocks are characteristic of the Chocolate Formation. In general, its base includes grey lava flows (basalts and basaltic andesites) as well as rhyolitic pyroclastites (Fig. A). Northeast of Tacna, pillow-lavas occur in the middle and upper parts of the formation. Thick ignimbrites (welded; with fiamme) are also observed. A number of hyaloclastites occur in the upper part of the unit, close to the overlying Liassic carbonates. The volcanic rocks mostly accumulated in a submarine environment (interbedded chert, pillow-lavas).

In several areas, petrographic and geochemical data indicate that the Chocolate rocks were produced in an arc setting by a calco-alcaline magmatism (Fig. B). REE data show a low fractionation of their light elements, with $La_N/Yb_N \approx 1\text{-}6$ in the Arequipa region, and $\approx 13\text{-}17$ in the Tacna region (Figs. C y D). Many Eu/Eu* ratios are low to very low, indicating some fractionation of plagioclase (Fig. E).

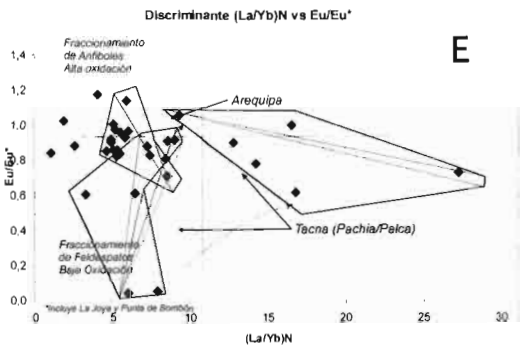
CONCLUSIONS AND INTERPRETATIONS

The Chocolate Formation was produced in an arc setting. It mostly consists of calco-alcaline basalts and andesites, but also includes some dacites and rhyolites. Occurrences of interbedded cherts and of pillow-lavas indicate that this thick arc succession at least in part accumulated below sea level.

Given the calco-alcaline arc context, the apparent variation in La_N/Yb_N ratio between Arequipa (1-6) and Tacna (6-17) suggests that magmatic processes and/or the composition of the crust were not uniform along the arc. Magmas were apparently less differentiated in the Arequipa region than in the Tacna region. Both types suggest that little garnet was present in the initial source, which is compatible with the idea that the crust was at that time relatively thin, albeit



irregular in thickness. This matches Pino et al.'s (2004) interpretation according to which accumulation of the Chocolate/Junerata Formation in the Tacna region was triggered and controlled by a long process of a lithospheric thinning.



Because it is likely that the Chocolate magmatism developed starting in the Late Paleozoic, the idea that it was produced by lithospheric thinning in the coastal region of southern Peru matches the conclusion that lithospheric thinning developed along the Eastern Cordillera of southern Peru during the mid-Permian - Triassic (Sempere et al., 2002). Sedimentary effects of lithospheric thinning are well recorded in the post-rift successions of coastal southernmost Peru (Pino et al., 2004), as well as the Western and Eastern cordilleras (Sempere et al., 2002). A main difference, however, is that lithospheric thinning in the coastal regions developed in the vicinity of a subduction arc, leaving open the possibility that back-arc extension led to the formation of a marginal basin.

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